IMPROVEMENT OF NON-UNIFORM NODE DEPLOYMENT MECHANISM FOR CORONA-BASED WIRELESS SENSOR NETWORKS

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To my beloved parents, my wife and daughters, sisters, brothers, supervisor and friends without your fully support, guidance and advice I might not had this kind of achievement.

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ABSTRACT

The promising technology of Wireless Sensor Networks (WSNs), lots of applications have been developed for monitoring and tracking in military, commercial, and educational environments. Imbalance energy of sensors causes significant reduction in the lifetime of the network. In corona-based Wireless Sensor Networks (WSNs), nodes that are positioned in coronas near the sink drain their energy faster than others as they are burdened with relaying traffic come from distant coronas forming energy holes in the network. This situation shows significant effects on the network efficiency in terms of lifetime and energy consumption. The network may stop operation prematurely even though there is much energy left unused at the distant nodes. In this thesis, non-uniform node deployments and energy provisioning strategies are proposed to mitigate energy holes problem. These strategies concerns the optimal number of sensors required in each corona in order to balance the energy consumption and to meet the coverage and connectivity requirements in the network. In order to achieve this aim, the number of sensors should be optimized to create sub-balanced coronas in the sense of energy consumption. The energy provisioning technique is proposed for harmonizing the energy consumption among coronas by computing the extra needed energy in every corona. In the proposed mechanism, the energy required in each corona for balanced energy consumption is computed by determining the initial energy in each node with respect to its corona, and according to the corona load while satisfying the network coverage and connectivity requirements. The theoretical design and modeling of the proposed sensors placement strategy promise a considerable improvement in the lifetime of corona-based networks. The proposed technique could improve the network lifetime noticeably via fair balancing of energy consumption ratio among coronas about 9.4 times more than other work. This is confirmed by the evaluation results that have been showed that the proposed solution offers efficient energy distribution that can enhance the lifetime about 40% compared to previous research works.

ABSTRAK

Teknologi yang menjanjikan Rangkaian Sensor Tanpa Wayar (WSN), banyak aplikasi telah dibangunkan untuk pemantauan dan penjejakan dalam persekitaran ketenteraan, komersial, dan pendidikan. Tenaga sensor imbangan menyebabkan pengurangan yang signifikan dalam jangka hayat rangkaian. Dalam Rangkaian Sensor Tanpa Wayar (WSN), yang berasaskan Corona, nod yang berada di koronas berhampiran sinki mengalirkan tenaga mereka lebih cepat daripada yang lain kerana mereka dibebani dengan menyampaikan trafik yang datang dari coronas jauh membentuk lubang tenaga dalam rangkaian. Keadaan ini menunjukkan kesan ketara ke atas kecekapan rangkaian dari segi penggunaan seumur hidup dan tenaga. Rangkaian itu mungkin berhenti beroperasi awal walaupun terdapat banyak tenaga yang tidak digunakan pada nod jauh. Dalam tesis ini, penggunaan nod bukan seragam dan strategi peruntukan tenaga dicadangkan untuk mengurangkan masalah lubang tenaga. Strategi ini merangkumi bilangan sensor yang diperlukan dalam setiap korona untuk mengimbangi penggunaan tenaga dan memenuhi keperluan perlindungan dan sambungan dalam rangkaian. Teknik peruntukan tenaga dicadangkan untuk menyelaraskan penggunaan tenaga di kalangan coronas dengan mengira tenaga tambahan yang diperlukan di setiap korona. Dalam mekanisme yang dicadangkan, tenaga yang diperlukan dalam setiap korona untuk penggunaan tenaga yang seimbang dikira dengan menentukan tenaga awal dalam setiap nod berkenaan dengan koronanya, dan mengikut beban corona sambil memenuhi liputan rangkaian dan keperluan sambungan. Reka bentuk teori dan pemodelan strategi penempatan sensor yang dicadangkan menjanjikan peningkatan yang besar dalam jangka hayat rangkaian berasaskan korona. Teknik yang dicadangkan ini dapat meningkatkan seumur hidup rangkaian secara nyata melalui pengimbangan seimbang nisbah penggunaan tenaga di kalangan coronas kira-kira 9.4 kali lebih banyak daripada kerja lain. Ini disahkan oleh hasil penilaian yang telah menunjukkan bahawa penyelesaian yang dicadangkan menawarkan pengagihan tenaga yang cekap yang dapat meningkatkan seumur hidup sekitar 40% berbanding dengan kerja penyelidikan sebelumnya.

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LIST OF SYMBOLS AND ABBREVIATION

WSN	-	Wireless Sensor Networks
LEACH	-	Low-Energy Adaptive Clustering Hierarchy
HEED	-	Hybrid, Energy-Efficient, Distributed
MLEACH	-	Mobile Low Energy Adaptive Clustering Hierarchy
UCR	-	Unequal Cluster-Based Routing
BS	-	Base Station
QoS	-	Quality Of Service
CH	-	Cluster Head
EPND	-	Energy Proportional Node Distribution
EBZNCH	-	Energy Balancing Zone-based Cluster Head
HUMS	-	Half-Quadrant-Based Moving Strategy
NLM	-	Network Limitation Maximization
CR	-	Centroid Region
EBCRP	-	Energy-Balancing Clustering Routing Protocol
EPT	-	Energy Provisioning Technique
RPs	-	Rendezvous Points
GND	-	Geometric Node Distribution
GUI	-	Graphical User Interface
PLE	-	Path Loss Exponent
NDSC	-	Node Deployment Strategy for Corona-based Wireless Sensor Networks
WRP	-	Weighted Rendezvous Planning
ε_0	-	Initial energy of each node
E_{elec}	-	Electronic energy consumption
r	-	Node transmission range
R	-	Network radius
α	-	Energy dissipate in the op-amp
M	-	Number of nodes in the network

N_{c_i}	-	Number of nodes in corona i
B	-	Packet length
n	-	Path loss exponent
k	-	Number of coronas in the network
w	-	Width of each corona
C_i	-	The ith corona
Z_{c_i}	-	The area of corona i
E_{rx}	-	The energy for data reception
E_{tx}	-	The energy for data transmission
w_i	-	The width of corona i
E_{c_i}	-	The energy consumption of corona i
L_{C_i}	-	The lifetime of corona i
γN	-	The proportional relation of nodes outside of corona i to nodes inside corona i
lt_{N_i}	-	The lifetime of a node in corona i
lt_{net}	-	The total lifetime of the network
E_{S_i}	-	The node energy for relaying a packet towards the sink
AE_{C_i}	-	The additional needed energy in corona i
$relayE_{c_i}$	-	The energy required for data relaying in corona i
SE_{c_i}	-	The energy needed to send the sensed data in corona i
E_{sx}	-	The energy for sensing a bit of data
THT	-	Tri-Hexagon Tiling
SH	-	Single-hop
MH	-	Multi-hop
FHS	-	Fixed hop size

CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless Sensor Networks (WSNs) consist of distributed sensor nodes designed to monitor environmental or physical conditions. Wireless sensors networking is a promising technology for a wide range of beneficial applications in several areas including civilian, military and smart homes. Sensor nodes in WSN communicate over short distances to complete different tasks. Due to the sensing capabilities of WSNs', they become a prominent choice for certain applications. Figure 1.1 shows some applications in Wireless Sensor Networks. The WSN can be used in tracing and tracking, mobile objects, animal tracking, enemy tracking, traffic tracking and human tracking. WSN can also be used in monitoring, such as security detection, inventory monitoring, telemedicine and health care monitoring, environmental monitoring, industrial monitoring and applications in military domains (Holger Karl, 2005; Bakshi, De, 2017; Ahmed et al.,2018).

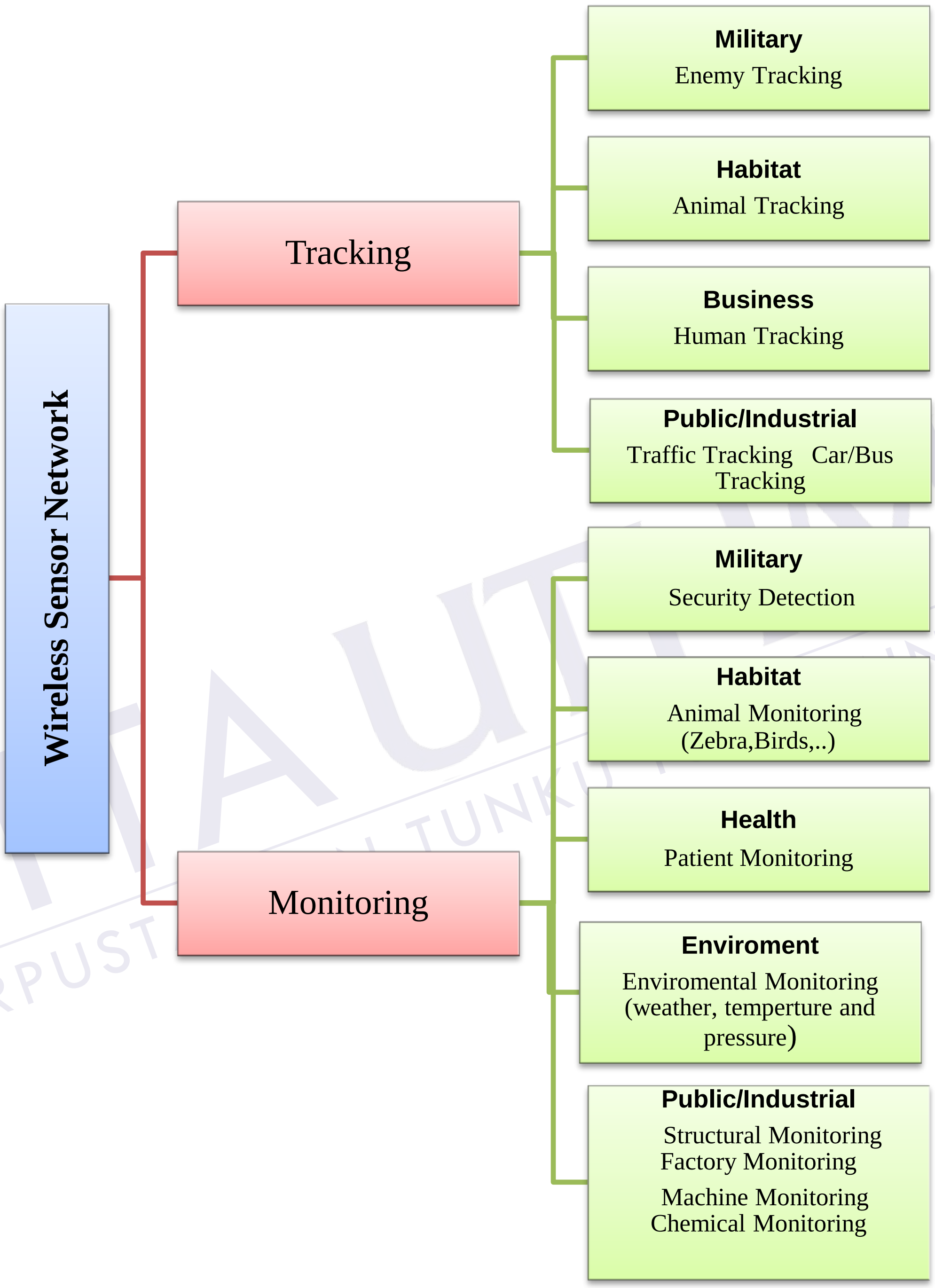

Figure1.1: Taxonomy of applications of wireless sensor networks (Yetgin, 2017)

WSN is considered as distributed architecture. It is composed of processing units that each has a separate processor, local memory, and input/output module. Due to the reason that sensors are not equipped with shared memory, they usually communicate with each other, thus creating a distributed communication network. The nodes in an area or regain transfer the collected information to the cluster node. The cluster node transmits the information collected from the sensors to a sink which is responsible for further processing, interpretation, and presentation of data to intended users. This transmission can be done using Internet, communications satellite or cable. Figures 1.2, 1.3 and 1.4 illustrate the sensor network architecture, the general diagrams of sensor node architecture, and sensor node software architecture, respectively (Sohraby, Minoli, Znati, 2007; Dymora, Mazurek, Nieroda, 2012; Raghavendra, Sivalingam, Znati, 2007).

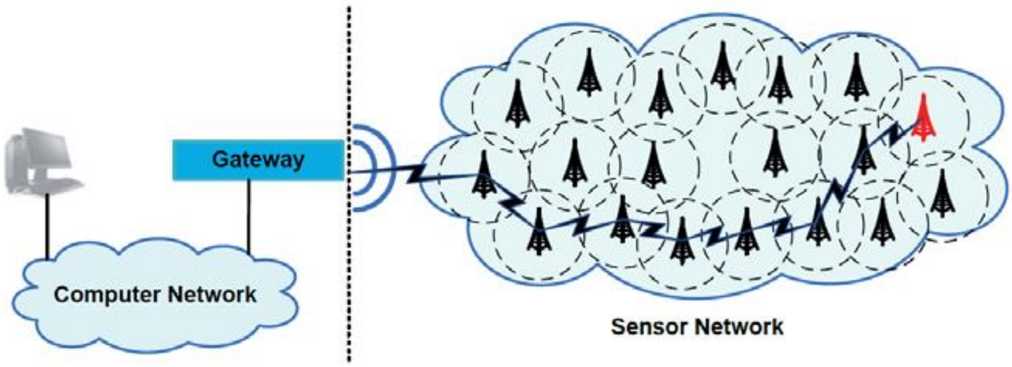

Figure1.2: The wireless sensor network architecture (Dymora et al., 2012).

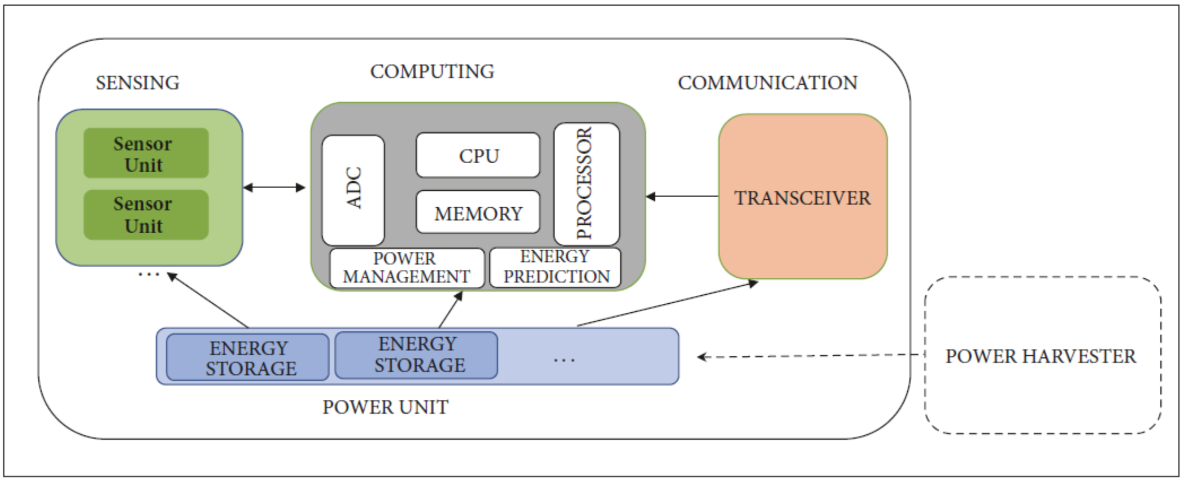

Figure 1.3: Sensor Node Architecture (K. S. Adu-Manu, 2017).

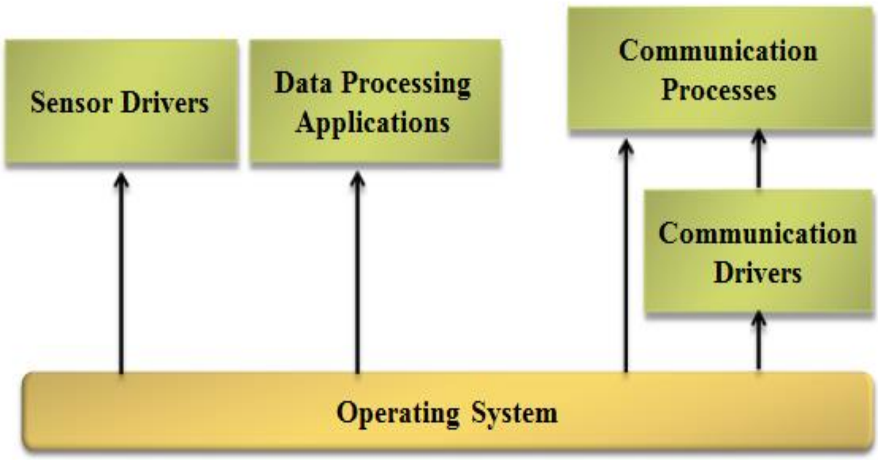

Figure 1.4: Sensor Software Architecture (Sohraby,2007)

1.2 Problem Statement

Network lifetime is one of the most significant issues in the WSN field. Network lifetime depends on active nodes and connectivity between them. When the energy of a node within a WSN is depleted, it dies and is disconnected from the sensor network, and the application of the network is no longer fully operational. Unbalanced energy amongst sensor nodes causes the network lifetime to decline considerably. In a corona-based WSN where sensor nodes are distributed in a circular area and a sink node is located at the centre of the area. When the many-to-one architecture is used, sensors placed around the sink relay the data from other sensors and consequently have heavier traffic loads. Those sensors dissipate more energy than other ones and their energy is depleted in greater speed, resulting in energy holes and hot spot regions. The energy holes problem is the most important factor that it decreases the network lifetime. Reducing the energy holes leads to improvement on the lifetime of sensor networks. When an energy hole appeared, information cannot be sent from other sensors to the sink even though most of the sensors still have sufficient energy. This means the network lifetime ends prematurely, and a large amount of energy is wasted. A corona in which its nodes die first is considered a critical corona, thus, the lifetime of WSN depends on lifetime of critical coronas. For that reason, energy must be conserved in an efficient way, to avoid energy holes that cause the increase of lifetime of sensor network.

1.3 Research Objectives

This research aims to alleviate and diminish energy hole problem in order to extend the operational time of the network by determining the best deployment that makes the highest network lifetime with desirable energy provisioning. Therefore, the research objectives are listed down as follows:

- To design a non-uniform node deployment that prolong the lifetime of the corona based wireless sensor networks.
- To investigate and implement an energy provisioning technique that can achieve the balanced energy depletion among sensor nodes in the network.
- To evaluate, verify and validate the performance of the proposed deployment strategy and energy provisioning technique using both MATLAB and OMNET++ environments.

1.4 Research Scope

This research concerns corona-based WSN where the width of each corona and the transmission range of each node is R. The process of data gathering includes that sensor nodes complete data reception and generating data messages and then transmitting the sensed data to the next hop node using multi-hop routing. All the nodes in the network are supposed to generate data at the same rate. Data aggregation is not assumed because data aggregation is indeed a possible solution for energy conservation. However, this solution needs to properly work with the routing algorithm. Since a specific routing algorithm. Data aggregation may not be considered in such a specific routing protocol. Furthermore, data aggregation may cause unbalanced energy consumption although it saves energy. Therefore, data aggregation is not further considered in this thesis. All the nodes have an initial energy and the sink/cluster-head has no energy limitation. The nodes in network distributed with uniform distance and the area is an environment that its path loss exponent is n and communication environment is contention-and error-free. MATLAB environment and OMNet++ were used as simulations.

1.5 Research Steps

In order to accomplish the goal of this research, the following research steps will be carried out:

i. Survey of existing mechanisms and strategies developed to solve or avoid energy hole problem in corona-based WSNs to identify key problem areas.

ii. Comparative performance evaluation of the existing solutions to explore their advantages and disadvantages.

iii. Exploring the concepts and mechanism that can be used to avoid energy hole problem in the presence of failure nodes, in addition to addressing the common issues that can affect the node energy provisioning.

iv. Design of the improvement non-uniform sensor node deployment strategy in addition to the energy provisioning technique, and mathematical verification of their components.

v. Implementation of the designed deployment strategy and energy provisioning technique for the purpose of validation in simulated sensor network environment.

vi. Performance evaluation of the designed strategy and technique to analyse their efficiency and measure their effect on the network lifetime by setting up a set of measurement parameters and scenarios to investigate the effectiveness and address the trade-off.

1.6 Findings and Contributions

The main contribution of this research is the design and development of a non-uniform sensor nodes deployment strategy. The proposed strategy aims to balance energy consumption ratio in each corona and also to maximise the network lifetime while maintaining the coverage and connectivity. The proposed strategy is designed based on energy provisioning concept to balance energy in all coronas. Therefore, the energy increment ratio needed for each corona to achieve balanced energy is calculated first. Then, the relationship between increasing the network lifetime and the required initial energy for each node in each corona is obtained. As the proposed strategy aims to balance energy consumption ratio in each corona and also to maximise the network lifetime while maintaining the coverage and connectivity, hence, the design and derivation of the related components has been verified and validated. It includes the calculation of the optimum number of sensor nodes required in the coronas, considering the balancing of the energy consumption in all coronas and maximum achievable lifetime of the network which meets coverage and connectivity requirements. The energy hole is an essential problem in Wireless Sensor Networks (WSNs) which caused by large amount of relayed sensed data by sensor nodes that are closer to the sink. The proposed strategy can help in improving the energy efficiency in addition to balancing the energy consumption, which leads to alleviate the energy hole and extend the network lifetime.

Therefore, the contributions of this research are listed as follows:

i. The optimal node deployment strategy for corona-based wireless sensor networks (NDSC) that improves the life time of the network and satisfies the applications requirements.

ii. Enhancement of the energy provisioning technique (EPT) that helps to balancing the energy and to extending the lifetime of corona based wireless sensor networks in the absence or failure of effective node deployment.

iii. Development of the nodes deployment strategy modules in MATLAB environment and OMNeT++ simulator according to the proposed mathematical systems.

1.7 Organisation of the Thesis

This thesis will be organised in six chapters as follows:

Chapter One provides a broad overview of the research. It presents an introduction to the importance of wireless sensor networks and the need for efficient deployment strategy of nodes in corona-based wireless sensor networks. The chapter presents the objectives, problem statement, scope and contributions of the research as well as the steps followed in carrying out this research.

Chapter Two covers the literature review that contains background material on wireless sensor networks (WSNs), which include their characteristics and challenges. The chapter presents a taxonomy and general classification of schemes developed for mitigating energy hole problem and discusses the most current and related works in this issue.

Chapter Three presents the experimental tools and methodologies that are used in this research. The chapter covers the common performance measurement tools used in evaluating WSNs, such as MATLAB and OMNet++, with description of their usage. It presents the development of the proposed node deployment strategy and the energy provisioning technique in the simulation.

Chapter Four presents the improvement non-uniform node deployment strategy and the energy provisioning technique proposed in this research. It presents the design objectives of the improvement deployment strategy and will describe the details of its structural design and formulation in addition to the description of the implementation and the algorithms needed for the operation procedures of the verification and validation purposes.

Chapter Five presents a detailed performance evaluation and comparison of the proposed improvement non-uniform node deployment strategy to the common uniform node deployment solution based on the numerical results obtained through simulations.

Chapter Six concludes the findings and contributions of this research and provides suggestions for possible future research.

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